before immersion by those who were unacquainted with the motives or circumstances of the experiment.

"To discover whether a similar change would be produced in the colour of the venous blood in hot air, a dog at 102° was placed in air at 134°. In ten minutes the temperature of the dog was 104½°, that of the air being 130°. In fifteen minutes the dog was 106°, the air 130°. A small quantity of blood was then taken from the jugular vein, the colour of which was sensibly altered, being much lighter than in the natural state. The effect produced by external heat on the colour of the venous blood seems to confirm the following opinion, which was first suggested by my worthy and ingenious friend, Mr. Wilson, of Glasgow. Admitting that the sensible heat of animals depends on the separation of absolute heat from the blood by means of its union with the phlogistic principle in the minute vessels, may there not be a certain temperature at which that fluid is no longer capable of combining with phlogiston, and at which it must of course cease to give off heat? It was partly with a view to investigate the truth of this opinion that Dr. Crawford was led to make the experiments recited above."

These views of Dr. Crawford and "his worthy and ingenious friend, Mr. Wilson,[1] of Glasgow," express, about as well as it was possible to express before the chemical discoveries of carbonic acid and oxygen, the now well-known truth that oxygen carried along with, but not chemically combined with, food in the arteries, combines with the carried food in the capillaries or surrounding tissues in the outlying regions and yields carbonic acid to the returning venous blood, this carbonic acid giving the venous blood its darker colour, and being ultimately rejected from the blood and from the body through the lungs, and carried away in the breath. Crawford's very important discovery that the venous blood of a dog which had been kept for some time in a hot-water bath at 112° Fahr. was almost undistinguishable from its arterial blood proves that it contained much less than the normal amount of carbonic acid, and that it may even have contained no carbonic acid at all. Chemical analysis of the breath in the circumstances would be most interesting; and it is to be hoped that this chemical experiment will be tried, not only on dogs, but on men. It seems, indeed, with our present want of experimental knowledge of animal thermodynamics, and with such knowledge as we have of physical thermodynamics, that the breath of an animal kept for a considerable time in a hot-water bath above the natural temperature of its body may be found to contain no carbonic acid at all. But even this would not explain the *generation of cold* which Dr. Crawford so clearly and pertinaciously pointed out. Very careful experimenting ought to be performed to ascertain whether or not there is a surplus of oxygen in the breath; more oxygen breathed out than taken in. If this is found to be the case, the *animal cold* would be explained by deoxidation (unburning) of matter within the body. If this matter is wholly or partly water, free hydrogen might be found in the breath; or the hydrogen of water left by oxygen might be disposed of in the body, in less highly oxygenated compounds than those existing when animal heat is wanted for keeping up the temperature of the body, or when the body is dynamically doing work.

BACTERIAL TREATMENT OF CRUDE SEWAGE.

THE fourth report on the experimental treatment of crude sewage in settling tanks and coke-beds has just been made public by the London County Council.[2] The work under notice was commenced in April, 1898, at the Barking and Crossness outfall works, where the sewage of the County of London and of certain neighbouring districts is discharged into the lower Thames.

The plan of experiment was suggested by the chemical adviser to the Council, and has been carried out under his direction and supervision, with the cooperation of the chemists and superintendents at the outfalls. A very small fraction of the sewage only has been thus treated, but in quality it has fairly represented the immense volume which arrives continuously from the sewer system of the metropolitan area. The results which are summarised in the report may therefore be looked upon as representative, and the conclusions and recommendations which have been founded upon them may be considered to be reasonably applicable to the entire metropolitan sewage discharge. The report gives a general *résumé* of the four years' experimental work, which has now led to results of so satisfactory a nature that the tentative treatment has been discontinued with the view of making a commencement of work on the large scale.

The early experiments were carried out with crude sewage, which had only been screened from its grosser suspended matters. This was allowed to flow into tanks filled with fragments of hard coke of uniform size. As soon as this bed was filled to the surface of the coke, the sewage was allowed to remain at rest for two or three hours and was then drained off from below. After the coke had remained for about five hours with air in the interstices, a second quantity of sewage was allowed to flow in as before. This cycle of processes was repeated for many months, and in some later experiments for more than a year.

The sewage was clarified by this treatment, but no purification from dissolved organic matter occurred in the early stages with a new bed. After the bed had been at work for about a week, however, it gradually began to effect a marked purification of the sewage from its dissolved putrescible matter. After two or three weeks, the contact of the sewage with the coke effected a removal of from 50 to 60 per cent. of the dissolved putrescible matter. This degree of purification was steadily maintained when the bed had been once "matured," and the effluent sewage was found to be non-putrescible even when it was maintained at summer-heat (80° F.) in an incubator. Hence the oxidisable organic matter which remained in the effluent was not such as would lead to offence when the effluent was discharged into an ordinary watercourse.

The treatment of the crude sewage, as judged by chemical criteria, was therefore successful. Dr. Houston, however, stated that, bacteriologically considered, this effluent was not appreciably better than the clear untreated sewage. But this he considered to be unimportant in the case of an effluent which was discharged into the muddy and brackish lower river, the water from which could never be used for drinking purposes.

A more serious difficulty, however, was soon encountered. It became necessary to ascertain what was the working sewage capacity of the coke-bed, in order to be able to state what area of land would be required to be laid down in coke-beds for the treatment of the whole of the London sewage. On gauging at frequent intervals the sewage capacity of a bed, it was found that the capacity decreased at a uniform and rapid rate, and that after use for about two years the bed would become practically choked and unable to receive its supply of sewage.

An examination of the coke surfaces showed that a gelatinous growth had formed upon them; this proved to be bacterial in nature, and necessary for producing the purifying effect. It was found, however, that this growth was impregnated with a certain amount of grit, evidently road detritus, and that woody fibre from the wood pavements and chaff and straw fragments from the horse droppings in the streets were also present in some quantity. It appeared that the gelatinous bacterial growth was a normal and necessary result and was definite in amount, but that the other matters derived from the street traffic accumulated on the coke and reduced the sewage capacity of the bed at an almost uniform rate.

Experiments on the preliminary sedimentation of the sewage were made by allowing it to flow through troughs and tanks on its way to the bed, and they proved that the gritty and cellulose matters could be almost completely separated from the sewage before it reached the coke-bed, and that this could be effected without allowing the comminuted fæcal matter to settle in any large degree. The matter thus separated by subsidence could be dried and in large part consumed in a destructor, the mineral portion being left as a useful clinker. The sedimented sewage was found to undergo satisfactory purification in the coke-bed without diminishing its sewage capacity.

It was evident that coke-beds must not be allowed to receive mineral detritus from the wear and tear of the roads, and that the cellulose matters derived from the roads were equally objectionable since they were not removed by bacterial action in the coke-bed as

[1] Who, no doubt, was Dr. Alex. Wilson, first professor of astronomy in the University of Glasgow (1760-1784); best known now for his ingenious views regarding sun-spots.

[2] "Bacterial Treatment of Sewage." Fourth Report by Dr. Clowes. Published for the County Council by P. S. King and Son, 2, Great Smith Street, Westminster.)

rapidly as they were introduced by the sewage. But both the grit and the cellulose matters could be separated by sedimentation; and the cellulose matters might, according to modern research, be slowly resolved by the action of suitable bacteria, if such could be established. Accordingly, it was arranged that the crude sewage should undergo a preliminary settlement in a deep tank, where the sediment should remain undisturbed in the hope that bacterial resolution of the organic matters in the deposit might occur.

This settling or so-called "septic" tank was found after a time to effect the resolution of the cellulose matters most satisfactorily, the necessary bacteria being evidently contained in the sewage. The amount of sediment which should have been found at the bottom of the tank was estimated by carefully gauging the volume of sewage which passed through the tank in the course of six months and determining the amount of suspended matter which the sewage contained. When the actual amount of sediment present in the tank at the end of this period was measured, it was found to correspond to about 50 per cent. of the total quantity introduced, and the sediment which remained consisted largely of the grit which had not been previously separated. It was therefore possible to dispose of the troublesome cellulose matter by long-maintained bacterial action in the settling tank, and to prevent it from clogging the coke-beds.

The final experimental stage consisted in passing the screened crude sewage through a settling tank, which was of such capacity that the sewage required five hours to pass through it and was so arranged that the sediment was undisturbed by the flow. The effluent from this tank was received successively in a series of coke-beds, in which it was treated in the way already described. After two hours' contact with the coke, it issued as an inoffensive and non-putrescible effluent which readily maintained the life of fish. The sediment in the settling tank was left entirely undisturbed. As soon as it had become permeated with its suitable bacteria, more than 50 per cent. of it was resolved into gaseous and soluble substances, and it was certain that a preliminary sedimentation of the grit must have further increased this percentage.

The sewage capacity of the coke-bed, on the other hand, was carefully gauged at intervals. It was found that the capacity diminished during the formation of the bacterial growth upon the coke surfaces, and that when this was complete the capacity of the bed was about 30 per cent. of the whole space which had been filled with coke and with sewage. No permanent alteration in capacity occurred during many months, although the capacity temporarily rose or fell by a few units per cent. from the average.

It appeared, therefore, that the above method of treatment was applicable to London sewage and that it might now be applied on the large scale. The experimental work was accordingly suspended, and the conclusions arrived at were stated and recommendations were framed in the following words:—

"*Conclusions arrived at by the Experimental Treatment.*

"(1) That by suitable continuous undisturbed sedimentation the raw sewage is deprived of matter which would choke the coke-beds, and the sludge which settles ou is reduced in amount by bacterial action to a very considerable extent. This reduction might undoubtedly be increased by the preliminary removal of road detritus.

"(2) That the coke-beds, after they have developed their full purifying power by use, have an average sewage capacity of about 30 per cent. of the whole space which has been filled with coke.

"(3) That the sewage capacity of the coke-bed, when the bed is fed with settled sewage, fluctuates slightly, but undergoes no permanent reduction. The bed does not choke, and its purifying power undergoes steady improvement for some time.

"(4) That coke of suitable quality does not disintegrate during use.

"(5) That the 'bacterial effluent' of settled sewage from the coke-beds does not undergo offensive putrefaction at all even in summer heat, and can never become offensive. That this effluent satisfactorily supports the respiration of fish.

"(6) That the use of chemicals is quite unnecessary under any circumstances when the above method of treatment is adopted.

"*Recommendations founded on the above Conclusions.*

"It would appear desirable, therefore, without delay, to commence the treatment of the London sewage by the above bacterial method. The construction of the necessary works will take time and will involve expenditure, but unless it is taken in hand, all considerations tend to show that owing to the increased abstraction of water by the water companies, both at their existing intakes and at the newly constructed reservoirs for storm water at Staines, a large portion of the lower river will continuously deteriorate. This deterioration would arise from the increase in the amount of the discharge of sewage effluent and the decrease in the upper river flush. Possible trouble arising from these causes will be absolutely prevented by adopting, under proper conditions and on a large scale, the treatment which has been strikingly successful on the experimental scale. It must be remembered that the condition of the river cannot be improved by any suddenly adopted action.

"If the treatment is introduced without delay and is gradually extended it may reasonably be expected that the increasing deterioration in the lower river water will first be checked and will ultimately be prevented; while the gradual development of the treatment will cause the expenditure to be spread over a period of years, and will prevent it from being unduly burdensome.

"It must be remembered that the present settling channels would serve, as at present, for settling purposes, but by the altered method of working them they would also act as sludge destroyers. They should, however, undoubtedly be preceded by grit chambers.

"It must be further borne in mind that the expense involved in the purchase and application of chemicals would be dispensed with."

Other conclusions, which were incidentally arrived at during the above experimental work, may be mentioned. The material used for filling the bacteria bed seems to exert no considerable influence on the purification obtained; coke proved to be the most efficient, ragstone containing calcium carbonate was less efficient, but the difference in efficiency was not of serious amount.

The depth of the coke-bed did not materially affect its efficiency between the limits tried, which ranged from four feet to twelve feet. In the interspaces of the coke, even in the deepest bed, a satisfactory proportion of oxygen was present in the air; the bed was able to aërate itself without mechanical aid.

The amount of sewage dealt with satisfactorily by the system of intermittent filling of the coke-bed described above was greater than that which could be similarly purified by a continuous supply furnished by sprinkling or by other methods of distribution.

The report concludes with detailed information concerning the bacterial treatment of their sewage by the authorities in forty-eight of the principal centres of population in this country. This information has been supplied by the responsible officers from the centres concerned and has been brought up to date of April 30, 1902.

A consideration of this information in conjunction with that supplied concerning the London experimental work will probably be felt to justify the opinion "that the process (of bacterial treatment of sewage) has been uniformly successful when the construction and use of the necessary plant has been reasonably and properly carried out," and that the metropolis may now safely adopt this "natural" method of sewage disposal.

FRANK CLOWES.

SILICA GLASS.

A FEW weeks ago we described some of the excellent results obtained by Messrs. Heraeus, of Hanau, in their attempts to produce apparatus of "silica glass," and Prof. Dewar has added point to our remarks by exhibiting at the Royal Institution a "liquid air holder" made of silica, which had been made to order and sent by return of post, almost, from Hanau to London a few days before. Similar apparatus could have been made in England, it is true, but it could not have been produced by any means so quickly as at Hanau. Now we receive from America an account of an animated discussion on the subject of "silica glass" which lately took place at a meeting of the American Electrochemical Society at Niagara Falls on the occasion of the reading of a paper, by Mr. R. S. Hutton, of Manchester, on his method of casting silica tubes in the electric furnace, which shows that our American cousins